Jan Becker Høgsberg - DTU Orbit (15/11/2017)

Jan Becker Høgsberg

Organisations

Maritime Engineering
30/11/2012 → 30/11/2012 Former
VIP

Coastal, Maritime and Structural Engineering
23/03/2012 → 10/05/2012 Former
VIP

Risø National Laboratory for Sustainable Energy
09/04/2008 → 07/04/2016 Former
VIP

Associate Professor, Department of Mechanical Engineering
04/07/2003 → present
jhg@mek.dtu.dk
VIP

Solid Mechanics
25/02/2012 → present
VIP

Publications:

Evaluation of damping estimates by automated Operational Modal Analysis for offshore wind turbine tower vibrations
Reliable predictions of the lifetime of offshore wind turbine structures are influenced by the limited knowledge concerning the inherent level of damping during downtime. Error measures and an automated procedure for covariance driven Operational Modal Analysis (OMA) techniques has been proposed with a particular focus on damping estimation of wind turbine towers. In the design of offshore structures the estimates of damping are crucial for tuning of the numerical model. The errors of damping estimates are evaluated from simulated tower response of an aeroelastic model of an 8 MW offshore wind turbine. In order to obtain algorithmic independent answers, three identification techniques are compared: Eigensystem Realization Algorithm (ERA), covariance driven Stochastic Subspace Identification (COV-SSI) and the Enhanced Frequency Domain Decomposition (EFDD). Discrepancies between automated identification techniques are discussed and illustrated with respect to signal noise, measurement time, vibration amplitudes and stationarity of the ambient response. The best bias-variance error trade-off of damping estimates is obtained by the COV-SSI. The proposed automated procedure is validated by real vibration measurements of an offshore wind turbine in non-operating conditions from a 24-h monitoring period.

General information
State: Published
Organisations: Department of Mechanical Engineering, Solid Mechanics, DONG Energy A/S
Authors: Bajrić, A. (Intern), Høgsberg, J. B. (Intern), Rüdinger, F. (Ekstern)
Pages: 153-163
Publication date: 2018
Main Research Area: Technical/natural sciences

Publication information
Journal: Renewable Energy
Volume: 116
ISSN (Print): 0960-1481
Ratings:
BFI (2017): BFI-level 1
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 4.83 SJR 1.697 SNIP 2.044
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 1.845 SNIP 2.118 CiteScore 4.51
Active tuned mass damper for damping of offshore wind turbine vibrations

An active tuned mass damper (ATMD) is employed for damping of tower vibrations of fixed offshore wind turbines, where the additional actuator force is controlled using feedback from the tower displacement and the relative velocity of the damper mass. An optimum tuning procedure equivalent to the tuning procedure of the passive tuned mass damper combined with a simple procedure for minimizing the control force is employed for determination of optimum damper parameters and feedback gain values. By time domain simulations conducted in an aeroelastic code, it is demonstrated that the ATMD can be used to further reduce the structural response of the wind turbine compared with the passive tuned mass damper and this without an increase in damper mass. A limiting factor of the design of the ATMD is the displacement of the damper mass, which for the ATMD, increases to compensate for the reduction in mass.
Characterization of clay-modified thermoset polymers under various environmental conditions for the use in high-voltage power pylons

The effect of nanoclay on various material properties like damping and strength of typical thermoset polymers, such as epoxy and vinyl ester, was investigated. Different environmental conditions typical for high-voltage transmission pylons made of composite materials were taken into account. Resin samples were prepared with various clay weight fractions ranging from 0% to 3%. Scanning electron microscopy, transmission electron microscopy, X-ray diffraction and rheological analysis were used to study the morphology and the structure of the nanocomposites. For all nanoclay-modified thermoset polymers, the morphology was found to be of exfoliated structure mainly. Static, uniaxial tensile tests showed that the addition of nanoclay to thermoset polymers led to a beneficial effect on the stiffness, whereas the tensile strength and ductility significantly decreased. When exposed to different environmental conditions, nanoclay was found to have a positive influence on the dynamic properties, analysed by a dynamic mechanical thermal analysis. The addition of nanoclay to the thermoset resin led to an increase of the damping properties by up to 28% for vinyl ester and up to 6% for epoxy at -20 degrees C. The dielectric properties were evaluated by electrical breakdown strength tests resulting in 11% better insulating behaviour for nanoclay-modified vinyl ester.

General information
State: Published
Organisations: Department of Mechanical Engineering, Solid Mechanics, Aalborg University, Technische Universität Dresden
Authors: Kliem, M. (Intern), Høgsberg, J. B. (Intern), Wang, Q. (Ekstern), Dannemann, M. (Ekstern)
Pages: 1-16
Publication date: 2017
Main Research Area: Technical/natural sciences

Publication information
Journal: Advances in Mechanical Engineering
Volume: 9
Issue number: 5
ISSN (Print): 1687-8132
Ratings:
Web of Science (2017): Indexed Yes
Scopus rating (2016): CiteScore 0.76 SJR 0.277 SNIP 0.589
Web of Science (2016): Indexed yes
Scopus rating (2015): SJR 0.253 SNIP 0.531 CiteScore 0.64
Scopus rating (2014): SJR 0.238 SNIP 0.498 CiteScore 0.63
Web of Science (2014): Indexed yes
Scopus rating (2013): SJR 0.348 SNIP 0.858 CiteScore 1.11
ISI indexed (2013): ISI indexed yes
Scopus rating (2012): SJR 0.378 SNIP 0.762 CiteScore 0.88
ISI indexed (2012): ISI indexed no
Scopus rating (2011): SJR 0.368 SNIP 1.183 CiteScore 1
ISI indexed (2011): ISI indexed no
Scopus rating (2010): SJR 0.102 SNIP 0
Original language: English
Nanoclay, Thermoset polymers, Material testing, Environmental ageing
Electronic versions:
1687814017698890.pdf
DOIs:
10.1177/1687814017698890
Numerical Investigation of Damping of Torsional Beam Vibrations by Viscous Bimoments

Damping of torsional beam vibrations of slender beam–structures with thin–walled cross–sections is investigated. Analytical results from solving the differential equation governing torsion with viscous bimoments imposed at the boundary, are compared with a numerical approach with three–dimensional, isoparametric elements. The viscous bimoments act on the axial warping displacements associated with inhomogeneous torsion, and are in a numerical format realized by suitable configurations of concentrated, axial forces describing discrete dampers. It is illustrated by an example that significant damping ratios may be obtained for a beam with an open cross–section.

General information
State: Published
Organisations: Department of Mechanical Engineering, Solid Mechanics
Authors: Hoffmeyer, D. (Intern), Høgsberg, J. B. (Intern)
Number of pages: 12
Publication date: 2017

Host publication information
Title of host publication: Proceedings of the 8th ECCOMAS Thematic Conference on Smart Structures and Materials
Publisher: European Community on Computational Methods in Applied Sciences
Editors: Güemes, A., Benjeddou, A., Rodellar, J., Leng, J.
Main Research Area: Technical/natural sciences
Conference: 8th ECCOMAS Thematic Conference on Smart Structures and Materials, Madrid, Spain, 05/06/2017 - 05/06/2017
Torsional beam vibrations, Damping, Warping, Viscous bimoment, Complex natural frequency, Finite element method
Publication: Research - peer-review › Article in proceedings – Annual report year: 2017

Accurate calibration of RL shunts for piezoelectric vibration damping of flexible structures

Piezoelectric RL (resistive-inductive) shunts are passive resonant devices used for damping of dominant vibration modes of a flexible structure and their efficiency relies on precise calibration of the shunt components. In the present paper improved calibration accuracy is attained by an extension of the local piezoelectric transducer displacement by two additional terms, representing the flexibility and inertia contributions from the residual vibration modes, not explicitly targeted by the shunt damping. This results in an augmented dynamic model for the targeted resonant vibration mode, in which the residual contributions, represented by two correction factors, modify both the apparent transducer capacitance and the shunt impedance. Explicit expressions for the correction of the shunt circuit inductance and resistance are presented in a form that is generally applicable to calibration formulae derived on the basis of an assumed single-mode structure, in which the modal interaction has been deliberately neglected. A design procedure is devised and subsequently verified by numerical examples, demonstrating that effective mitigation can be obtained for an arbitrary vibration mode when the residual mode correction is included in the calibration of the RL shunt.

General information
State: Published
Organisations: Department of Mechanical Engineering, Solid Mechanics
Authors: Høgsberg, J. B. (Intern), Krenk, S. (Intern)
Number of pages: 11
Publication date: 2016

Host publication information
Title of host publication: Proceedings of the 27th International Conference on Adaptive Structures and Technologies (ICAST 2016)
Main Research Area: Technical/natural sciences
Conference: 27th International Conference on Adaptive Structures and Technologies (ICAST 2016), Lake George, NY, United States, 03/10/2016 - 03/10/2016
Electronic versions: ICAST_2016_hogsberg_krenk.pdf
Analysis of hybrid viscous damper by real time hybrid simulations

Results from real time hybrid simulations are compared to full numerical simulations for a hybrid viscous damper, composed of a viscous dashpot in series with an active actuator and a load cell. By controlling the actuator displacement via filtered integral force feedback the damping performance of the hybrid viscous damper is improved, while for pure integral force feedback the damper stroke is instead increased. In the real time hybrid simulations viscous damping is emulated by a bang-bang controlled Magneto-Rheological (MR) damper. The controller activates high-frequency modes and generates drift in the actuator displacement, and only a fraction of the measured damper force can therefore be used as input to the investigated integral force feedback in the real time hybrid simulations.

General information
State: Published
Organisations: Department of Mechanical Engineering, Solid Mechanics, Purdue University
Authors: Brodersen, M. L. (Intern), Ou, G. (Ekstern), Høgsberg, J. B. (Intern), Dyke, S. (Ekstern)
Pages: 675-688
Publication date: 2016
Main Research Area: Technical/natural sciences

Publication information
Journal: Engineering Structures
Volume: 126
ISSN (Print): 0141-0296
Ratings:
BFI (2017): BFI-level 2
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 2.93 SJR 1.578 SNIP 2.048
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.696 SNIP 2.195 CiteScore 2.59
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.756 SNIP 2.56 CiteScore 2.4
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 2.049 SNIP 2.853 CiteScore 2.69
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 1.855 SNIP 2.627 CiteScore 2.23
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 1.7 SNIP 2.735 CiteScore 2.26
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 1.76 SNIP 2.343
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 1.764 SNIP 2.167
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 1.473 SNIP 2.033
Scopus rating (2007): SJR 1.581 SNIP 2.137
Calibration of piezoelectric RL shunts with explicit residual mode correction

Piezoelectric RL (resistive-inductive) shunts are passive resonant devices used for damping of dominant vibration modes of a flexible structure and their efficiency relies on the precise calibration of the shunt components. In the present paper improved calibration accuracy is attained by an extension of the local piezoelectric transducer displacement by two additional terms, representing the flexibility and inertia contributions from the residual vibration modes not directly addressed by the shunt damping. This results in an augmented dynamic model for the targeted resonant vibration mode, in which the residual contributions, represented by two correction factors, modify both the apparent transducer capacitance and the shunt circuit impedance. Explicit expressions for the correction of the shunt circuit inductance and resistance are presented in a form that is generally applicable to calibration formulae derived on the basis of an assumed single-mode structure, where modal interaction has been neglected. A design procedure is devised and subsequently verified by a numerical example, which demonstrates that effective mitigation can be obtained for an arbitrary vibration mode when the residual mode correction is included in the calibration of the RL shunt.

General information
State: Published
Organisations: Department of Mechanical Engineering, Solid Mechanics
Authors: Høgsberg, J. B. (Intern), Krenk, S. (Intern)
Pages: 65-81
Publication date: 2016
Main Research Area: Technical/natural sciences

Publication information
Journal: Journal of Sound and Vibration
Volume: 386
ISSN (Print): 0022-460x
Ratings:
BFI (2017): BFI-level 2
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.09 SJR 1.462 SNIP 2.162
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.391 SNIP 2.142 CiteScore 2.71
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.447 SNIP 2.38 CiteScore 2.54
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 1.391 SNIP 2.64 CiteScore 2.61
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
Damping of Torsional Beam Vibrations by Control of Warping Displacement

Supplemental damping of torsional beam vibrations is considered by viscous bimoments acting on the axial warping displacement at the beam supports. The concept is illustrated by solving the governing eigenvalue problem for various support configurations with the applied bimoments represented as viscous boundary conditions. It is demonstrated that properly calibrated viscous bimoments introduce a significant level of supplemental damping to the targeted vibration mode and that the attainable damping can be accurately estimated from the two undamped problems associated with vanishing and infinite viscous parameters, respectively.

General information

State: Published
Organisations: Department of Mechanical Engineering, Solid Mechanics, Rambøll Danmark A/S
Authors: Høgsberg, J. B. (Intern), Hoffmeyer, D. (Intern), Ejlersen, C. (Ekstern)
Number of pages: 5
Publication date: 2016
Main Research Area: Technical/natural sciences
Explicit solution for the natural frequency of structures with partial viscoelastic treatment

The free vibration characteristics of structures with viscoelastic treatment are represented by the complex-valued natural frequencies. The assumed single mode representation associated with the low-frequency stiffness of the viscoelastic treatment is modified by a correction term representing the influence from residual vibration modes. The correction term is eliminated in terms of the corresponding natural frequency associated with the high-frequency stiffness of the viscoelastic treatment, whereby an expression is obtained for the complex-valued natural frequency, which only requires the solution of two real-valued eigenvalue problems.
Hybrid damper with stroke amplification for damping of offshore wind turbines

The magnitude of tower vibrations of offshore wind turbines is a key design driver for the feasibility of the monopile support structure. A novel control concept for the damping of these tower vibrations is proposed, where viscous-type hybrid dampers are installed at the bottom of the wind turbine tower. The proposed hybrid damper consists of a passive viscous dashpot placed in series with a load cell and an active actuator. By integrated force feedback control of the actuator motion, the associated displacement amplitude over the viscous damper can be increased compared with the passive viscous case, hereby significantly increasing the feasibility of viscous dampers acting at the bottom of the wind turbine tower. To avoid drift in the actuator displacement, a filtered time integration of the measured force signal is introduced. Numerical examples demonstrate that the filtered time integration control leads to performance similar to that of passive viscous damping and substantial amplification of the damper deformation without actuator drift. Copyright © 2016 John Wiley & Sons, Ltd.

General information
State: Published
Organisations: Department of Mechanical Engineering, Solid Mechanics
Authors: Brodersen, M. L. (Intern), Høgsberg, J. (Intern)
Number of pages: 16
Pages: 2223–2238
Publication date: 2016
Main Research Area: Technical/natural sciences

Publication information
Journal: Wind Energy
Volume: 19
Issue number: 12
ISSN (Print): 1095-4244
Ratings:
BFI (2017): BFI-level 2
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.37 SJR 1.104 SNIP 2.306
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.196 SNIP 2.086 CiteScore 3.06
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.272 SNIP 3.75 CiteScore 3.42
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 1.275 SNIP 2.464 CiteScore 2.75
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 1.126 SNIP 2.39 CiteScore 2.36
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 1.024 SNIP 2.718 CiteScore 2.49
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 1.487 SNIP 2.013
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 1.124 SNIP 1.448
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 2
Hybrid viscous damper with filtered integral force feedback control

In hybrid damper systems active control devices are usually introduced to enhance the performance of otherwise passive dampers. In the present paper a hybrid damper concept is comprised of a passive viscous damper placed in series with an active actuator and a force sensor. The actuator motion is controlled by a filtered integral force feedback strategy, where the main feature is the filter, which is designed to render a damper force that in a phase-plane representation operates in front of the corresponding damper velocity. It is demonstrated that in the specific parameter regime where the damper force leads velocity the control is stable and yields a significant improvement in damping performance compared to the pure viscous damper.
Optimization of neural networks for time-domain simulation of mooring lines

When using artificial neural networks in methods for dynamic analysis of slender structures, the computational effort associated with time-domain response simulation may be reduced drastically compared to classic solution strategies. This article demonstrates that the network structure of an artificial neural network, which has been trained to simulate forces in a mooring line of a floating offshore platform, can be optimized and reduced by different optimization procedures. The procedures both detect and prune the least salient network weights successively, and besides trimming the network, they also can be used to rank the importance of the various network inputs. The dynamic response of slender marine structures often depends on several external load components, and by applying the optimization procedures to a trained artificial neural network, it is possible to classify the external force components with respect to importance and subsequently determine which of them may be ignored in the analysis. The performance of the optimization procedures is illustrated by a numerical example, which shows that, in particular, the most simple procedures are able to remove more than half of the network weights in an artificial neural network without significant loss of simulation accuracy.

General information
State: Published
Organisations: Department of Mechanical Engineering, Department of Applied Mathematics and Computer Science, Cognitive Systems, Solid Mechanics, DNV GL A/S
Authors: Christiansen, N. H. (Intern), Voie, P. E. T. (Ekstern), Winther, O. (Intern), Høgsberg, J. B. (Intern)
Pages: 434-443
Publication date: 2016
Main Research Area: Technical/natural sciences
Resonant Electromagnetic Shunt Damping of Flexible Structures

Electromagnetic transducers convert mechanical energy to electrical energy and vice versa. Effective passive vibration damping of flexible structures can therefore be introduced by shunting with an accurately calibrated resonant electrical network that contains a capacitor to create the desired resonance and a resistor to dissipate the correct amount of vibration energy. The modal interaction with residual vibration forms not targeted by the resonant shunt is represented by supplemental flexibility and inertia terms. This leads to modified calibration formulae that maintain the desired damping performance in the case of flexible structures with substantial modal interaction.
Resonant passive–active vibration absorber with integrated force feedback control

A general format of a two-terminal vibration absorber is constructed by placing a passive unit in series with a hybrid unit, composed of an active actuator in parallel with a second passive element. The displacement of the active actuator is controlled by an integrated feedback control with the difference in force between the two passive elements as input. This format allows passive and active contributions to be combined arbitrarily within the hybrid unit, which results in a versatile absorber format with guaranteed closed-loop stability. This is demonstrated for resonant absorbers with inertia realized passively by a mechanical inerter or actively by the integrated force feedback. Accurate calibration formulae are presented for two particular absorber configurations and the performance is subsequently demonstrated with respect to both equal modal damping and effective response reduction.
Structural modelling of composite beams with application to wind turbine rotor blades

The ever changing structure and growing size of wind turbine blades put focus on the accuracy and flexibility of design tools. The present thesis is organized in four parts - all concerning the development of efficient computational methods for the structural modelling of composite beams which will support future growth in the rotor size. The first part presents a two-node beam element formulation, based on complementary elastic energy, valid for fully coupled beams with variable cross-section properties. The element stiffness matrix is derived by use of the six equilibrium states of the element corresponding to tension, torsion, bending, and shear. This approach avoids the need for explicit interpolation of kinematic variables and provides a direct locking-free formulation. The formulation includes a consistent representation of distributed loads and enables recovery of the exact internal force distributions. In the second part a formulation developed for analysis of the stiffness properties of general cross-sections with arbitrary geometry and material distribution is presented. The full six by six cross-section stiffness matrix is obtained by imposing simple deformation modes on a single layer of 3D finite elements. The method avoids the development of any special 2D theory for the stress and strain distributions and enables a simple and direct representation of material discontinuities and general anisotropy via their well-established representation in 3D elements. The third part presents an extension of the 3D cross-section analysis by an efficient Finite Element modelling approach for thin and thick-walled sections which substantially reduces the meshing effort. The approach is based on discretizing the walls of the section using a single layer of displacement based elements with the layers represented within the elements. A post processing scheme is also presented to recover inter laminar stresses via equilibrium equations of 3D elasticity derived in the laminate coordinate system. In the final part of the thesis a flexible method for analysing two types of instabilities associated with bending of thin-walled prismatic beams is presented. First, the flattening instability from the Brazier effect is modelled by representing the cross-section by two-dimensional non-linear co-rotating beam elements with imposed in-plane loads proportional to the curvature. Second, the bifurcation instability from longitudinal stresses is modelled with a Finite Strip buckling analysis based on the deformed cross-section. The analysis is well suited for early stages of design as it only requires a simple 2D line mesh of the cross-section.
Tuned resonant mass or inerter-based absorbers: unified calibration with quasi-dynamic flexibility and inertia correction

A common format is developed for a mass and an inerter-based resonant vibration absorber device, operating on the absolute motion and the relative motion at the location of the device, respectively. When using a resonant absorber a specific mode is targeted, but in the calibration of the device it may be important to include the effect of other non-resonant modes. The classic concept of a quasi-static correction term is here generalized to a quasi-dynamic correction with a background inertia term as well as a flexibility term. An explicit design procedure is developed, in which the background effects are included via a flexibility and an inertia coefficient, accounting for the effect of the non-resonant modes. The design procedure starts from a selected level of dynamic amplification and then determines the device parameters for an equivalent dynamic system, in which the background flexibility and inertia effects are introduced subsequently. The inclusion of background effect of the non-resonant modes leads to larger mass, stiffness and damping parameter of the device. Examples illustrate the relation between resonant absorbers based on a tuned mass or a tuned inerter element, and demonstrate the ability to attain balanced calibration of resonant absorbers also for higher modes.
Artificial Neural Networks for Reducing Computational Effort in Active Truncated Model Testing of Mooring Lines

As oil and gas exploration moves to deeper waters the need for methods to conduct reliable model experiments increases. It is difficult obtain useful data by putting a scaled model of an entire mooring line systems into an ocean basin test facility. A way to conduct more realistic experiments is by active truncated models. In these models only the very top part of the system is represented by a physical model whereas the behavior of the part below the truncation is calculated by numerical models and accounted for in the physical model by active actuators applying relevant forces to the physical model. Hence, in principal it is possible to achieve reliable experimental data for much larger water depths than what the actual depth of the test basin would suggest. However, since the computations must be faster than real time, as the numerical simulations and the physical experiment run simultaneously, this method is very demanding in terms of numerical efficiency and computational power. Therefore, this method has not yet proved to be feasible. It has recently been shown how a hybrid method combining classical numerical models and artificial neural networks (ANN) can provide a dramatic reduction in computational effort when performing time domain simulation of mooring lines. The hybrid method uses a classical numerical model to generate simulation data, which are then subsequently used to train the ANN. After successful training the ANN is able to take over the simulation at a speed two orders of magnitude faster than conventional numerical methods. The AAN ability to learn and predict the nonlinear relation between a given input and the corresponding output makes the hybrid method tailor made for the active actuators used in the truncated experiments. All the ANN training can be done prior to the experiment and with a properly trained ANN it is no problem to obtain accurate simulations much faster than real time-without any need for large computational capacity. The present study demonstrates how this hybrid method can be applied to the active truncated experiments yielding a system where the demand for numerical efficiency and computational power is no longer an issue.

General information
State: Published
Organisations: Department of Mechanical Engineering, Solid Mechanics, DNV Denmark A/S, DNV GL A/S
Authors: Christiansen, N. H. (Ekstern), Voie, P. E. T. (Ekstern), Høgsberg, J. B. (Intern)
Number of pages: 10
Publication date: 2015

Host publication information
Title of host publication: Proceedings of the ASME 34th International Conference on Ocean, Offshore and Arctic Engineering
Balanced calibration of resonant piezoelectric RL shunts with quasi-static background flexibility correction

Resonant RL shunt circuits constitute a robust approach to piezoelectric damping, where the performance with respect to damping of flexible structures requires a precise calibration of the corresponding circuit components. The balanced calibration procedure of the present paper is based on equal damping of the two modes associated with the resonant vibration form of the structure, when including a quasi-static contribution from non-resonant vibration modes via a single background flexibility parameter. Explicit calibration formulae are presented, and it is demonstrated by a numerical example that the procedure leads to equal modal damping and effective response reduction, even for rather indirect placement of the transducer, provided that the correction for background flexibility is included in the calibration procedure.
A method is presented for analysis of the properties of general cross-sections with arbitrary geometry and material distribution. The full six by six cross-section stiffness matrix is evaluated from a single element thickness slice represented by 3D solid elements with lengthwise Hermitian interpolation with six independent imposed deformation modes corresponding to extension, torsion, bending and shear. The flexibility matrix of the slice is obtained from complementary elastic energy, and the stiffness matrix is obtained by extracting and inverting the cross-section flexibility. Three examples illustrate the accuracy of the method for solid and thin-walled sections with isotropic and general anisotropic materials.
Damping of wind turbine tower vibrations

Damping of wind turbine tower vibrations by supplemental dampers is a key ingredient for the continuous use of monopiles as support for offshore wind turbines. The present thesis consists of an extended summary with four parts and appended papers [P1-P4] concerning novel strategies for damping of tower dominated vibrations. The first part of the thesis presents the theoretical framework for implementation of supplemental dampers in wind turbines. It is demonstrated that the feasibility of installing dampers at the bottom of the tower is significantly increased when placing passive or semiactive dampers in a stroke amplifying brace, which amplifies the displacement across the damper and thus reduces the desired level of damper force. For optimal damping of the two lowest tower modes, a novel toggle-brace concept for amplifying the bending deformation of the tower is presented. Numerical examples illustrate that a minimum of three braces in a symmetric circumferential configuration are needed to introduce homogeneous damping in the two lowest vibration modes, independent of the rotor direction. A novel hybrid viscous damper concept is described in the second part. The hybrid damper consists of a viscous dashpot in series with an actuator and a load cell. The controllable actuator displacement is regulated by an Integral Force Feedback (IFF) with the measured force from the load cell as sensor input. By controlling the actuator displacement exactly 180° out of phase with the damper force, the displacement across the passive viscous dashpot is increased, thus improving the feasibility of placing dampers at the root of the wind turbine tower. Furthermore, attainable damping can be increased when introducing a filtered version of the proposed IFF control, and explicit design concepts are presented in the thesis. An Active Tuned Mass Damper (ATMD) concept is described in the third part of the thesis. By controlling the supplemental actuator force with absolute tower displacement and relative damper velocity as sensor input a stable control scheme is constructed for effective damping by the ATMD of the two critical tower modes. The frequency response performance of the ATMD is equivalent to that of the passive Tuned Mass Damper, but with a reduced damper mass. Furthermore, it is demonstrated that the active control force can be significantly reduced. Finally, in the last part the performance of the hybrid viscous damper with IFFs validated by a series of real time hybrid simulations (RTHS). The experimental results illustrate the ability of the hybrid damper concept to increase damper stroke or attainable damping. The results also show that the actuator signal is quite sensitive to drift due an offset in the measured damper force. Thus, for the stroke amplifying IFF control a filtered integration is introduced, which almost retains the desired amplification and reduces drift. For the filtered IFF control, aimed at enhancing attainable damping, an augmented filtering similarly reduces drift, but also deteriorates the damping performance.

General information

State: Published
Organisations: Department of Mechanical Engineering, Solid Mechanics, Fluid Mechanics, Coastal and Maritime Engineering
Authors: Brodersen, M. L. (Intern), Høgsberg, J. B. (Intern), Jensen, J. J. (Intern), Pedersen, M. M. (Ekstern)
Number of pages: 142
Publication date: 2015

Publication information

Place of publication: Kgs. Lyngby
Publisher: Technical University of Denmark (DTU)
ISBN (Print): 978-87-7475-455-8
Original language: English

Series: DCAMM Special Report
Number: S203
ISSN: 0903-1685
Main Research Area: Technical/natural sciences
Electronic versions:
S203_Mark_Laier_Brodersen_PhD_Thesis.pdf

Relations

Projects:

Damping of wind turbine tower vibrations
Publication: Research › Ph.D. thesis – Annual report year: 2016

Piezoelectric RL shunt damping of flexible structures

Resonant RL shunt circuits represent a robust and effective approach to piezoelectric damping, provided that the individual shunt circuit components are calibrated accurately with respect to the dynamic properties of the corresponding flexible structure. The balanced calibration procedure applied in the present analysis is based on equal damping of the two modes associated with the resonant vibration form of the structure. An important result of the presented calibration procedure is the explicit inclusion of a quasi-static contribution from the non-resonant vibration modes of the structure via a single background flexibility parameter. This leads to explicit calibration expressions for the shunt circuit components and it is demonstrated by a simple numerical example that the procedure with correction for background flexibility leads to both equal damping of the two modes and effective response reduction.

General information
Analysis of moderately thin-walled beam cross-sections by cubic isoparametric elements

In technical beam theory the six equilibrium states associated with homogeneous tension, bending, shear and torsion are treated as individual load cases. This enables the formulation of weak form equations governing the warping from shear and torsion. These weak form equations are solved numerically by introducing a cubic-linear two-dimensional isoparametric element. The cubic interpolation of this element accurately represents quadratic shear stress variations along cross-section walls, and thus moderately thin-walled cross-sections are effectively discretized by these elements. The ability of this element to represent curved geometries, and to accurately determine cross-section parameters and shear stress distributions is demonstrated.
Comparison of Neural Network Error Measures for Simulation of Slender Marine Structures

Training of an artificial neural network (ANN) adjusts the internal weights of the network in order to minimize a predefined error measure. This error measure is given by an error function. Several different error functions are suggested in the literature. However, the far most common measure for regression is the mean square error. This paper looks into the possibility of improving the performance of neural networks by selecting or defining error functions that are tailor-made for a specific objective. A neural network trained to simulate tension forces in an anchor chain on a floating offshore platform is designed and tested. The purpose of setting up the network is to reduce calculation time in a fatigue life analysis. Therefore, the networks trained on different error functions are compared with respect to accuracy of rain flow counts of stress cycles over a number of time series simulations. It is shown that adjusting the error function to perform significantly better on a specific problem is possible. On the other hand, it is also shown that weighted error functions actually can impair the performance of an ANN.
Damping of Offshore Wind Turbine Tower Vibrations by a Stroke Amplifying Brace

The potential of installing dampers inside the tower of an offshore wind turbine is investigated through simulations. Dampers are installed at the bottom to act on the curvature of the tower, and it is shown that dampers installed in suitable braces have the potential to increase the critical damping ratio of the two lowest tower modes by 1 percent. By using a toggle-brace system, damper stroke is increased, while the damper force is reduced. Finally, by installing the dampers in a symmetric configuration, tuning for maximum damping is approximately independent of the orientation of the rotor, thereby making this installation of dampers feasible.

General information
State: Published
Organisations: Department of Mechanical Engineering, Solid Mechanics
Authors: Brodersen, M. L. (Intern), Høgsberg, J. B. (Intern)
Number of pages: 10
Damping of Wind Turbine Tower Vibrations by a stroke amplifying brace concept

General information
State: Published
Organisations: Department of Mechanical Engineering, Solid Mechanics
Authors: Brodersen, M. L. (Intern), Høgsberg, J. B. (Intern)
Number of pages: 28
Publication date: 2014

Publication information
Media of output: PowerPoint
Original language: English
Main Research Area: Technical/natural sciences
Electronic versions:
Damping_of_wind_turbine_tower.pdf

Publication: Research › Sound/Visual production (digital) – Annual report year: 2014
Explicit solution format for complex-valued natural frequency of beam with R-shunted piezoelectric laminate transducer

Analysis and design of resistive shunt circuits for piezoelectric damping of beam structures is often based on a representation in terms of the single target vibration mode of the beam, neglecting spill-over effects from the out-of-bandwidth or residual vibration modes. In this article, a solution format is derived for the complex-valued natural frequency of the beam with a shunted piezoelectric laminate transducer, where the influence from the residual modes is taken into account by a quasi-static representation. This explicit solution format contains system parameters that directly represent the authority of the transducer and the spill-over from residual modes, and it recovers the short- and open-circuit frequencies as limit solutions. Furthermore, the frequency solution format provides the basis for design expressions for the optimal resistance and the corresponding attainable damping of the beam. The accuracy of the explicit frequency solution format is verified by comparison with numerical results. It is found that the complex-valued natural frequency of the first vibration mode of a beam with a piezoelectric laminate transducer shunted to a resistance is estimated with sufficient accuracy for engineering design purposes.

General information
State: Published
Organisations: Department of Mechanical Engineering, Solid Mechanics, Ecole Normale Superieure de Cachan
Authors: Høgsberg, J. B. (Intern), Cœnt, A. L. (Ekstern)
Pages: 31-44
Publication date: 2014
Main Research Area: Technical/natural sciences

Publication information
Volume: 228
Issue number: 1
ISSN (Print): 0954-4062
Ratings:
BFI (2017): BFI-level 1
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Scopus rating (2016): SJR 0.35 SNIP 0.706 CiteScore 0.92
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.369 SNIP 0.635 CiteScore 0.78
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 0.407 SNIP 0.848 CiteScore 0.77
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 0.377 SNIP 0.821 CiteScore 0.79
ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 0.4 SNIP 0.949 CiteScore 0.75
ISI indexed (2012): ISI indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 0.324 SNIP 0.835 CiteScore 0.67
ISI indexed (2011): ISI indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 0.325 SNIP 0.932
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 0.293 SNIP 0.593
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 0.245 SNIP 0.584
Scopus rating (2007): SJR 0.3 SNIP 0.573
Scopus rating (2006): SJR 0.384 SNIP 0.881
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 0.429 SNIP 0.688
Scopus rating (2004): SJR 0.353 SNIP 0.7
Scopus rating (2003): SJR 0.292 SNIP 0.745
Scopus rating (2002): SJR 0.328 SNIP 0.754
This paper validates numerically and experimentally a new neural network-based real-time force tracking scheme for magnetorheological (MR) dampers on a five-storey shear frame with MR damper. The inverse model is trained with absolute values of measured velocity and force because the targeted current is a positive quantity. The validation shows accurate results except of small current spikes when the desired force is in the vicinity of the residual MR damper force. In the closed-loop, higher frequency components in the current are triggered by the transition of the actual MR damper force from the pre-yield to the post-yield region. A control-oriented approach is presented to compensate for these drawbacks. The resulting control force tracking scheme is validated for the emulation of viscous damping, clipped viscous damping with negative stiffness, and friction damping with negative stiffness. The tests indicate that the proposed tracking scheme works better when the frequency content of the estimated current is close to that of the training data. Copyright © 2013 John Wiley & Sons, Ltd.
Hybrid Method Simulation of Slender Marine Structures

This present thesis consists of an extended summary and five appended papers concerning various aspects of the implementation of a hybrid method which combines classical simulation methods and artificial neural networks. The thesis covers three main topics. Common for all these topics is that they deal with time domain simulation of slender marine structures such as mooring lines and flexible risers used in deep sea offshore installations. The first part of the thesis describes how neural networks can be designed and trained to cover a large number of different sea states. Neural networks can only recognize patterns similar to those comprised in the data used to train the network. Fatigue life evaluation of marine structures often considers simulations of more than a hundred different sea states. Hence, in order for this method to be useful, the training data must be arranged so that a single neural network can cover all relevant sea states. The applicability and performance of the present hybrid method is demonstrated on a numerical model of a mooring line attached to a floating offshore platform. The second part of the thesis demonstrates how sequential neural networks can be used to simulate dynamic response of specific critical hot spots on a flexible riser. In the design of mooring lines only top tension forces are considered. These forces can easily be determined by a single neural network. Riser design, depending on the applied configuration, requires detailed analysis of several critical hot spots along the structure. This means that the relation between external loading and corresponding structural response is not necessarily as direct as for the mooring line example. Hence, one neural network is not sufficient to cover the entire structure. It is demonstrated how a series of neural networks can be set up to sequentially simulate the dynamic response at critical locations along a complex riser structure. The final part of the thesis deals with the optimization of neural networks. It is shown how trained networks can be dramatically reduced in size while still maintaining a high simulation accuracy. Beside providing a more compact neural network the optimization procedures can be used to rank the importance of external effects on structures. Such sensitivity studies usually require numerous simulations. But by using this method these studies can be based on just one short simulation sequence which reduces the computational cost significantly. The great advantage with the hybrid method is that it gives rise to significant reductions in computation time associated with nonlinear dynamic time domain simulations. However, since the neural network depends on pre-generated training data, one must always consider the balance between saved computation time and time spend on establishing the hybrid method.

General information
State: Published
Organisations: Department of Mechanical Engineering, Solid Mechanics
Authors: Christiansen, N. H. (Intern), Sødahl, N. (Ekstern), Høgsberg, J. B. (Intern)
Number of pages: 114
Publication date: 2014

Publication information
Publisher: DTU Mechanical Engineering
ISBN (Print): 978-87-7475-410-7
Original language: English
Series: DCAMM Special Report
Number: S182
ISSN: 0903-1685
Main Research Area: Technical/natural sciences
Electronic versions:
Hybrid_Method_Simulation.pdf
Publication: Research › Ph.D. thesis – Annual report year: 2015
Optimized Mooring Line Simulation Using a Hybrid Method Time Domain Scheme
Dynamic analyses of slender marine structures are computationally expensive. Recently it has been shown how a hybrid method which combines FEM models and artificial neural networks (ANN) can be used to reduce the computation time spend on the time domain simulations associated with fatigue analysis of mooring lines by two orders of magnitude. The present study shows how an ANN trained to perform nonlinear dynamic response simulation can be optimized using a method known as optimal brain damage (OBD) and thereby be used to rank the importance of all analysis input. Both the training and the optimization of the ANN are based on one short time domain simulation sequence generated by a FEM model of the structure. This means that it is possible to evaluate the importance of input parameters based on this single simulation only. The method is tested on a numerical model of mooring lines on a floating offshore installation. It is shown that it is possible to estimate the cost of ignoring one or more input variables in an analysis.

General information
State: Published
Organisations: Department of Mechanical Engineering, Solid Mechanics, DNV Denmark A/S, Det Norske Veritas
Authors: Christiansen, N. H. (Ekstern), Voie, P. E. T. (Ekstern), Høgsberg, J. (Intern), Sodahl, N. (Ekstern)
Number of pages: 10
Publication date: 2014

Tuned mass absorber on a flexible structure
The classic design of a tuned mass absorber is based on a simple two-mass analogy in which the tuned mass is connected to the structural mass with a spring and a viscous damper. In a flexible multi-degree-of-freedom structure the tuned mass absorber is typically introduced to provide damping of a specific mode. The motion of the point of attachment of the tuned mass absorber to the structure has not only a contribution from the targeted mode, but also a background contribution from other non-resonant modes. Similarly, the force provided by the tuned mass absorber is distributed between the targeted mode and the background modes. It is demonstrated how this effect can be included via a non-dimensional dynamic background flexibility coefficient, extracted from a classic modal analysis for the particular frequency of the selected mode. An explicit calibration procedure is developed starting with the desired maximum amplification, from which the device damper, mass and stiffness are determined, accounting for the background flexibility. Examples demonstrate the influence of the flexibility effect and the efficiency of the proposed procedure.

General information
State: Published
Organisations: Department of Mechanical Engineering, Solid Mechanics
Authors: Krenk, S. (Intern), Høgsberg, J. B. (Intern)
Pages: 1577-1595
Publication date: 2014
Main Research Area: Technical/natural sciences

Publication information
Journal: Journal of Sound and Vibration
Volume: 333
Issue number: 6
ISSN (Print): 0022-460X
Ratings:
BFI (2017): BFI-level 2
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.09 SJR 1.462 SNIP 2.162
Beam section stiffness properties using 3D finite elements

The cross-section properties of a beam is characterized by a six by six stiffness matrix, relating the six generalized strains to the conjugate section forces. The problem is formulated as a single-layer finite element model of a slice of the beam, on
which the six deformation modes are imposed via Lagrange multipliers. The Lagrange multipliers represent the constraining forces, and thus combine to form the cross-section stiffness matrix. The theory is illustrated by a simple isotropic cross-section.

**Efficient Mooring Line Fatigue Analysis Using a Hybrid Method Time Domain Simulation Scheme**

Dynamic analyses of mooring line systems are computationally expensive. Over the last decades an extensive variety of methods to reduce this computational cost have been suggested. One method that has shown promising preliminary results is a hybrid method which combines finite element analysis and artificial neural networks (ANN). The present study presents a novel strategy for selecting, arranging and normalizing training data for an ANN. With this approach one ANN can be trained to perform high speed dynamic response prediction for all fatigue relevant sea states and cover both wave frequency motion and slow drift motion. The method is tested on a mooring line system of a floating offshore platform. After training a full fatigue analysis is carried out. The results show that the ANN with high precision provides top tension force histories two orders of magnitude faster than a full dynamic analysis. Copyright © 2013 by ASME.

**Equal modal damping design for a family of resonant vibration control formats**

The principle of equal modal damping is used to give a unified presentation and calibration of resonant control of structures for different control formats, based on velocity, acceleration–position or position feedback. When introducing a resonant controller the original resonant mode splits into two, and if these are required to have the same modal damping ratio, the characteristic equation conforms to a two-parameter format. By selecting a suitable relative separation of the modal frequencies, the design problem defines a one-parameter family – determined, for example, in terms of the resulting
modal damping ratio. While velocity feedback, and the associated acceleration–position formats, lead to near-equal resonant peak heights of the velocity in a frequency response diagram, position feedback leads to balanced acceleration peaks. It is demonstrated, how a simple additional time derivative term in the control coupling can change these properties into balanced position and velocity peaks, respectively. In particular this gives an improved control format based on measurement of structural displacement or deformation. In all cases the optimal calibration in terms of a root locus identification leads to a simple explicit pair of design formulae for controller frequency and damping ratio based on a simple two -degrees-of-freedom system. Unconditional stability is demonstrated for a general multi-degrees-of-freedom system with multiple controllers for the velocity and acceleration-velocity formats, while the position and extended position feedback format give a simple stability condition in terms of the gain factors and the structure flexibility matrix. The paper concludes with a simple design procedure based on the desired effective damping of a flexible structure with equal modal control in any of the discussed resonant formats.

**General information**
- **State:** Published
- **Organisations:** Department of Mechanical Engineering, Solid Mechanics
- **Authors:** Krenk, S. (Intern), Høgsberg, J. B. (Intern)
- **Pages:** 1294-1315
- **Publication date:** 2013
- **Main Research Area:** Technical/natural sciences

**Publication information**
- **Journal:** Journal of Vibration and Control
- **Volume:** 19
- **Issue number:** 9
- **ISSN (Print):** 1077-5463
- **Ratings:**
  - BFI (2017): BFI-level 1
  - Web of Science (2017): Indexed Yes
  - BFI (2016): BFI-level 1
  - Scopus rating (2016): CiteScore 1.16 SJR 0.531 SNIP 0.806
  - Web of Science (2016): Indexed yes
  - BFI (2015): BFI-level 1
  - Scopus rating (2015): SJR 0.57 SNIP 0.894 CiteScore 1.12
  - Web of Science (2015): Indexed yes
  - BFI (2014): BFI-level 1
  - Scopus rating (2014): SJR 0.587 SNIP 1.041 CiteScore 1.08
  - BFI (2013): BFI-level 1
  - Scopus rating (2013): SJR 0.727 SNIP 1.139 CiteScore 2.74
  - ISI indexed (2013): ISI indexed yes
  - Web of Science (2013): Indexed yes
  - BFI (2012): BFI-level 1
  - Scopus rating (2012): SJR 0.488 SNIP 0.953 CiteScore 1.33
  - ISI indexed (2012): ISI indexed yes
  - Web of Science (2012): Indexed yes
  - BFI (2011): BFI-level 1
  - Scopus rating (2011): SJR 0.457 SNIP 1.204 CiteScore 1.35
  - ISI indexed (2011): ISI indexed yes
  - BFI (2010): BFI-level 1
  - Scopus rating (2010): SJR 0.478 SNIP 1.017
  - BFI (2009): BFI-level 1
  - Scopus rating (2009): SJR 0.71 SNIP 1.165
  - BFI (2008): BFI-level 2
  - Scopus rating (2008): SJR 0.606 SNIP 1.031
  - Web of Science (2008): Indexed yes
  - Scopus rating (2007): SJR 0.559 SNIP 0.973
  - Scopus rating (2006): SJR 0.452 SNIP 0.889
  - Scopus rating (2005): SJR 0.421 SNIP 0.958
  - Web of Science (2005): Indexed yes
Experimental calibration of forward and inverse neural networks for rotary type magnetorheological damper

This paper presents a systematic design and training procedure for the feed-forward backpropagation neural network (NN) modeling of both forward and inverse behavior of a rotary magnetorheological (MR) damper based on experimental data. For the forward damper model, with damper force as output an optimization procedure demonstrates accurate training of the NN architecture with only current and velocity as input states. For the inverse damper model, with current as output, the absolute value of velocity and force are used as input states to avoid negative current spikes when tracking a desired damper force. The forward and inverse damper models are trained and validated experimentally, combining a limited number of harmonic displacement records, and constant and half-sinusoidal current records. In general the validation shows accurate results for both forward and inverse damper models, where the observed modeling errors for the inverse model can be related to knocking effects in the measured force due to the bearing plays between hydraulic piston and MR damper rod. Finally, the validated models are used to emulate pure viscous damping. Comparison of numerical and experimental results demonstrates good agreement in the post-yield region of the MR damper, while the main error of the inverse NN occurs in the pre-yield region where the inverse NN overestimates the current to track the desired viscous force. Copyright © 2013 Techno-Press, Ltd.
Statics and Mechanics of Structures

The statics and mechanics of structures form a core aspect of civil engineering. This book provides an introduction to the subject, starting from classic hand-calculation types of analysis and gradually advancing to a systematic form suitable for computer implementation. It starts with statically determinate structures in the form of trusses, beams and frames. Instability is discussed in the form of the column problem - both the ideal column and the imperfect column used in actual column design. The theory of statically indeterminate structures is then introduced, and the force and deformation methods are explained and illustrated. An important aspect of the book's approach is the systematic development of the theory in a form suitable for computer implementation using finite elements. This development is supported by two small computer programs, MiniTruss and MiniFrame, which permit static analysis of trusses and frames, as well as linearized stability analysis. The book's final section presents related strength of materials subjects in greater detail; these include stress and strain, failure criteria, and normal and shear stresses in general beam flexure and in beam torsion.

General information

State: Published
Organisations: Department of Mechanical Engineering, Solid Mechanics
Authors: Krenk, S. (Intern), Høgsberg, J. B. (Intern)
Number of pages: 506
Publication date: 2013

Publication information

Publisher: Springer Science+Business Media B.V.
ISBN (Print): 978-94-007-6112-4
ISBN (Electronic): 978-94-007-6113-1
Original language: English
Main Research Area: Technical/natural sciences
Links:
Source: dtu
Source-ID: u::8347
Publication: Research - peer-review › Book – Annual report year: 2013

A Family of Resonant Vibration Control Formats

Resonant control makes use of a controller with a resonance frequency and an equivalent damping ratio. A simple explicit calibration procedure is presented for a family of resonant controllers in which the frequency
is tuned to the natural frequency of the targeted mode in such a way that the two resulting modes exhibit identical damping ratio. This tuning is independent of the imposed controller damping. The controller damping is then selected as an optimal compromise between too small damping, and too large damping at which the modal frequencies coincide, and thereby produce undesirable constructive interference. This 'equal modal damping' procedure leads to explicit calibration formulae, and produces a nearly level plateau in the frequency response curve with lower response than the traditional double-root calibration.

**General information**
State: Published
Organisations: Department of Mechanical Engineering, Solid Mechanics
Authors: Krenk, S. (Intern), Høgsberg, J. B. (Intern)
Number of pages: 8
Publication date: 2012
Event: Paper presented at EACS 2012, Genoa, Italy.
Main Research Area: Technical/natural sciences
Resonant damping, Active control, Structural vibration
Electronic versions:
eacs2012_krenk_hogsberg.pdf
Source: dtu
Source-ID: u::5624
Publication: Research - peer-review › Paper – Annual report year: 2012

**Balanced calibration of resonant shunt circuits for piezoelectric vibration control**
Shunting of piezoelectric transducers and suitable electric circuits constitutes an effective passive approach to resonant vibration damping of structures. Most common design concepts for resonant resistor-inductor (RL) shunt circuits rely on either maximization of the attainable modal damping or minimization of the frequency response amplitude. However, the former is suboptimal near resonance due to constructive interference of the two modes with identical frequency, and the latter results in reduced implemented damping. This article proposes an explicit pole placement–based design procedure for both series and parallel RL circuits. The procedure relies on equal modal damping and sufficient separation of the complex poles to avoid constructive interference of the two modes. By comparison with existing design procedures, it is demonstrated that the present calibration leads to a balanced compromise between large modal damping and effective response reduction with limited damping effort.

**General information**
State: Published
Organisations: Department of Mechanical Engineering, Solid Mechanics
Authors: Høgsberg, J. (Intern), Krenk, S. (Intern)
Pages: 1937-1948
Publication date: 2012
Main Research Area: Technical/natural sciences

**Publication information**
Journal: Journal of Intelligent Material Systems and Structures
Volume: 23
Issue number: 17
ISSN (Print): 1045-389X
Ratings:
BFI (2017): BFI-level 1
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 2.02 SJR 0.707 SNIP 1.141
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.891 SNIP 1.584 CiteScore 2.37
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 1.045 SNIP 1.811 CiteScore 2.54
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 1.03 SNIP 1.981 CiteScore 2.84
ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 1.025 SNIP 1.579 CiteScore 1.87
ISI indexed (2012): ISI indexed yes
Balanced Design of Resonant Shunted Piezoelectric Vibration Control

General information

State: Published
Organisations: Department of Mechanical Engineering, Solid Mechanics
Authors: Høgsberg, J. B. (Intern), Krenk, S. (Intern)
Publication date: 2012
Event: Abstract from 8th European Solid Mechanics Conference, Graz, Austria.
Main Research Area: Technical/natural sciences
Electronic versions:
Source: dtu
Source-ID: u::5625
Publication: Research - peer-review › Conference abstract for conference – Annual report year: 2012

Modelling and Control of Magnetorheological Damper: Real-time implementation and experimental verification

This thesis considers two main issues concerning the application of a rotary type magnetorheological (MR) damper for damping of flexible structures. The first is the modelling and identification of the damper property, while the second is the formulation of effective control strategies. The MR damper is identified by both the standard parametric Bouc-Wen model and the non-parametric neural network model from an experimental data set generated by dynamic tests of the MR damper mounted in a hydraulic testing machine. The forward model represents the direct dynamics of the MR damper where velocity and current are used as input and the force as output. The inverse model represents the inverse dynamics of the MR damper where the absolute velocity and absolute force are used as input and the damper current as output. For the inverse model the current output of the network must always be positive, and it is found that the modelling error of the inverse model is significantly reduced when the corresponding input is given in terms of the absolute values of velocity and damper force. This is a new contribution to the inverse modelling techniques for the control of MR dampers. Another new contribution to the modelling of an MR damper is the use of experimental measurement data of a rotary MR damper that requires appropriate filtering. The semi-systematic optimisation procedure proposed in the thesis derives an effective neural network structure, where only velocity and damper force are essential input parameters for the MR damper modelling. Thus, for proper training, the quality of the velocity data is very important. However, direct velocity measurement is not easy. From the displacement data or the acceleration data, velocity can be determined by using simple differentiation or integration, respectively, but
the apparent negative stiffness to the control of the MR damper significantly decreases both the top floor displacement and the acceleration amplitudes of the shear frame structure. The structural damping ratios obtained from the response curves of the experiments correspond well to the expected values. This indicates that the mean stiffness and mean energy dissipation of the control forces are predicted fairly accurate.

A final numerical investigation is based on a classic benchmark problem for earthquake protection of a multi storey building. The seismic response of the base-isolated benchmark building with an MR damper installed between the ground and the base is illustrated, and the effectiveness of negative stiffness of the control strategies is verified numerically. Similarly, the response of another wind excited benchmark building installed with MR dampers is demonstrated and the response amplitude can often be given explicitly by e.g. maximizing the damping ratio of the targeted vibration mode. Consequently the idea behind this trained neural network is that the optimal properties of the desired hysteretic loop formulation can be extrapolated to more general and non-harmonic response patterns, e.g. narrow-band stochastic response due to wind, wave, traffic or even earthquake excitation.

Numerical and experimental simulations have been conducted to examine the performance of the proposed control strategies. Force tracking by using an inverse neural network of the MR damper is improved by a low-pass filter to reduce the noise in the desired current and a simple switch that truncates negative values of the desired current. The performance of the collocated control schemes for the rotary type semi-active MR damper are initially verified by closed loop dynamic experiments conducted on a 5-storey shear frame structure exposed to harmonic base excitation. The MR damper is mounted on the structure so that it operates on the relative motion between the ground base and the first floor of the shear frame. The shear frame structural model is initially experimentally identified, where mass and stiffness of the model is determined by an inverse modal analysis based on the natural frequencies obtained experimentally. The damping matrix is subsequently determined from the estimated damping ratio obtained by free decay tests. The results in the thesis demonstrate that introducing negative stiffness to the control of the MR damper significantly decreases both the top floor displacement and acceleration amplitudes of the shear frame structure. The structural damping ratios obtained from the response curves of the experiments correspond well to the expected values. This indicates that the mean stiffness and mean energy dissipation of the control forces are predicted fairly accurate.

The main contributions to this thesis are the novel modelling approach to the direct and the inverse dynamics of a rotary MR damper from experimental data, the development of model based semi-active control strategies for the MR damper, the effective introduction of negative stiffness in the control of semi-active dampers and the demonstration of effectiveness and closed loop implementation of the control techniques on both a shear frame structure and a numerical benchmark problem.

General information
State: Published
Organisations: Department of Mechanical Engineering, Solid Mechanics, Swiss Federal Laboratories for Materials Testing and Research
Authors: Bhowmik, S. (Intern), Høgsberg, J. B. (Intern), Krenk, S. (Intern), Weber, F. (Ekstern)
Number of pages: 198
Publication date: 2012

Publication information
Publisher: DTU Mechanical Engineering
Original language: English
Series: DCAMM Special Report
Number: S139
ISSN: 0903-1685
Optimal Brain Surgeon on Artificial Neural Networks in

It is shown how the procedure know as optimal brain surgeon can be used to trim and optimize artificial neural networks in nonlinear structural dynamics. Beside optimizing the neural network, and thereby minimizing computational cost in simulation, the surgery procedure can also serve as a quick input parameter study based on one simulation only.

Resonant vibration control of three-bladed wind turbine rotors

Rotors with blades, as in wind turbines, are prone to vibrations due to the flexibility of the blades and the support. In the present paper a theory is developed for active control of a combined set of vibration modes in three-bladed rotors. The control system consists of identical collocated actuator-sensor pairs on each of the blades, and targets a set of three modes constituting a collective mode with identical motion of all the blades, and two independent whirling modes, in which a relative motion pattern moves forward or backward over the rotor. The natural frequency of the collective mode is typically lower than the frequency of the whirling modes due to support flexibility. The control signals from the blades are combined into a mean signal, addressing the collective mode, and three components from which the mean signal has be subtracted, addressing the pair of whirling modes. The response of the actuators is tuned to provide resonant damping of the collective mode and the whirling modes by using the separate resonance characteristics of the collective and the whirling modes. In the calibration of the control parameters it is important to account for the added flexibility of the structure due to influence of other nonresonant modes. The efficiency of the method is demonstrated by application to a rotor with 42 m blades, where the sensor/actuator system is implemented in the form of an axial extensible strut near the root of each blade. The load is provided by a simple but fully threedimensional correlated wind velocity field. It is shown by numerical simulations that the active damping system can provide a significant reduction in the response amplitude of the targeted modes, while applying control moments to the blades that are about 1 order of magnitude smaller than the moments from the external load. Copyright © 2011.
Wind Turbine Rotors with Active Vibration Control

This thesis presents a framework for structural modeling, analysis and active vibration damping of rotating wind turbine blades and rotors. A structural rotor model is developed in terms of finite beam elements in a rotating frame of reference. The element comprises a representation of general, varying cross-section properties and assumes small cross-section displacements and rotations, by which the associated elastic stiffness and inertial terms are linear. The formulation consistently describes all inertial terms, including centrifugal softening and gyroscopic forces. Aerodynamic lift forces are assumed to be proportional to the relative inflow angle, which also gives a linear form with equivalent stiffness and
damping terms. Geometric stiffness effects including the important stiffening from tensile axial stresses in equilibrium with centrifugal forces are included via an initial stress formulation. The element provides an accurate representation of the eigenfrequencies and whirling modes of the gyroscopic system, and identifies lightly damped edge-wise modes. By adoption of a method for active, collocated resonant vibration of multi-degree-of-freedom systems it is demonstrated that the basic modes of a wind turbine blade can be effectively addressed by an in-blade ‘active strut’ actuator mechanism. The importance of accounting for background mode flexibility is demonstrated. Also, it is shown that it is generally possible to address multiple beam modes with multiple controllers, given that these are geometrically well separated. For active vibration control in three-bladed wind turbine rotors the present work presents a resonance-based method for groups of one collective and two whirling modes. The controller is based on the existing resonant format and introduces a dual system targeting the collective mode and the combined whirling modes respectively, via a shared set of collocated sensor/actuator pairs. The collective mode controller is decoupled from the whirling mode controller by an exact linear filter, which is identified from the fundamental dynamics of the gyroscopic system. As in the method for non-rotating systems, an explicit procedure for optimal calibration of the controller gains is established. The control system is applied to an 86m wind turbine rotor by means of active strut actuator mechanisms. The prescribed additional damping ratios are reproduced almost identically in the targeted modes and the observed spill-over to other modes is very limited and generally stabilizing. It is shown that physical controller positioning for reduced background noise is important to the calibration. By simulation of the rotor response to both simple initial conditions and a stochastic wind load it is demonstrated that the amplitudes of the targeted modes are effectively reduced, while leaving the remaining modes virtually unaffected.

**General information**

**State:** Published  
**Organisations:** Department of Mechanical Engineering, Coastal, Maritime and Structural Engineering  
**Authors:** Svendsen, M. N. (Intern), Krenk, S. (Intern), Høgsberg, J. B. (Intern)  
**Publication date:** Mar 2011

**Publication information**

**Place of publication:** Kgs. Lyngby, Denmark  
**Publisher:** Technical University of Denmark (DTU)  
**Original language:** English  
**Series:** DCAMM Special Report  
**Number:** S122  
**ISSN:** 0903-1685  
**Main Research Area:** Technical/natural sciences  
**Electronic versions:**  
S122 Martin Nyman Svendsen.pdf

**Bibliographical note**

Danish title: Modalkontrol af vindmøller  
Source-ID: 314149  
Publication: Research › Ph.D. thesis – Annual report year: 2011

**Artificial Neural Networks for Nonlinear Dynamic Response Simulation in Mechanical Systems**

It is shown how artificial neural networks can be trained to predict dynamic response of a simple nonlinear structure. Data generated using a nonlinear finite element model of a simplified wind turbine is used to train a one layer artificial neural network. When trained properly the network is able to perform accurate response prediction much faster than the corresponding finite element model. Initial result indicate a reduction in cpu time by two orders of magnitude.

**General information**

**State:** Published  
**Organisations:** Coastal, Maritime and Structural Engineering, Department of Mechanical Engineering, Cognitive Systems, Department of Informatics and Mathematical Modeling  
**Authors:** Christiansen, N. H. (Intern), Høgsberg, J. B. (Intern), Winther, O. (Intern)  
**Publication date:** 2011

**Host publication information**

**Title of host publication:** Proceedings of the 24th Nordic Seminar on Computational Mechanics  
**Main Research Area:** Technical/natural sciences  
**Conference:** NSCM-24, Helsinki, Finland, 01/01/2011  
**Nonlinear structural dynamics, Artificial neural networks**  
**Electronic versions:**  
prod21321948946741.NSCM-24_main[1].pdf  
Source: orbit
Relaxation Model for Control of Flexible Structures

Relaxation Model for Control of Flexible Structures

Relaxation Model for Control of Flexible Structures

Resonant Damping of Flexible Structures Under Random Excitation, in Computational Methods in Stochastic Dynamics

Resonant Damping of Flexible Structures Under Random Excitation, in Computational Methods in Stochastic Dynamics

Resonant Vibration Control Formats with Equal Modal Damping: Extended Abstract

Resonant Vibration Control Formats with Equal Modal Damping: Extended Abstract

Resonant vibration control of rotating beams

Resonant vibration control of rotating beams

Resonant vibration control of rotating beams
The role of negative stiffness in semi-active control of magneto-rheological dampers

The performance of external dampers depends on the particular combination of energy dissipation and stiffness, where in general damping increases with decreasing damper stiffness. It is therefore of great interest to minimize or even introduce negative damper stiffness. The present paper proposes adaptive control strategies for the applied voltage of a semi-active magneto-rheological damper. From linear equivalent models obtained by harmonic averaging it is found that these control strategies introduce equivalent negative stiffness, and by numerical simulations it is illustrated that they lead to improved response reduction compared to the corresponding case with optimal viscous damping.
Neural Network modeling of forward and inverse behavior of rotary MR damper

Magneto-rheological (MR) dampers have received considerable attention within the last decades, mainly because of their design simplicity, low power requirements, large force range and robustness. The most common models to describe the dynamic MR damper behavior are the Bouc-Wen model, the LuGre friction model and the Dahl friction model. However, these mathematical approaches might be complicated due to the high degree of nonlinearity in the system under consideration. From a computational point of view the nonparametric neural network technique is very versatile in connection with most types of nonlinear problems. The present paper concerns the nonparametric neural network modeling of the dynamic behavior of a rotary MR damper. A rotary type MR damper consists of a rotating disk which is enclosed in a metallic housing filled with the MR fluid which is operated in shear mode. The dissipative torque produced is transformed into a translational force through the crank shaft mechanism. A feed-forward back propagation neural network is used to model both the forward and the inverse dynamics of the MR damper. The forward model output is the estimated force and therefore can be used later as observer. The inverse model is needed to solve the force tracking task when the MR damper is used for structural damping. The training and validation data are obtained from tests of the MR damper on a hydraulic test set-up for sinusoidal and triangular displacement at different frequencies and amplitudes and for constant and half-sinusoidal currents. The half-sinusoidal current as input is chosen because the emulation of linear viscous damping results almost in a half-sinusoidal current time history if the current spike during the pre-yield region is neglecting. The forward model is trained with the inputs velocity and current and the force as the goal. The velocity is derived from the measured displacement by numerical differentiation which requires additional low pass filtering besides the nominal filtering of the measured states to remove measurement noise and offsets. The inverse model is trained with the absolute values of velocity and force as input data and the resulting current as the goal. This new approach is chosen because the current is always positive independent of the signs of velocity and force. The validations of both the forward and the inverse models with the proposed neural network approach show acceptably small modeling errors.
**Optimal Tuning of Amplitude Proportional Coulomb Friction Damper for Maximum Cable Damping**

This paper investigates numerically the optimal tuning of Coulomb friction dampers on cables, where the optimality criterion is maximum additional damping in the first vibration mode. The expression for the optimal friction force level of Coulomb friction dampers follows from the linear viscous damper via harmonic averaging. It turns out that the friction force level has to be adjusted in proportion to cable amplitude at damper position which is realized by amplitude feedback in real time. The performance of this adaptive damper is assessed by simulated free decay curves from which the damping is estimated. It is found that the damping efficiency agrees well with the expected value at the theoretical optimum. However, maximum damping is larger and achieved at a force to amplitude ratio of 1.4 times the analytical value. Investigations show that the increased damping results from energy spillover to higher modes evoked by the amplitude proportional Coulomb friction damper which clamps the cable at its upper and lower positions. The resulting nonsinusoidal cable motion clearly violates the assumption of pure harmonic motion and explains why such dampers have to be tuned differently from optimal linear viscous dampers.

**General information**

State: Published
Organisations: Coastal, Maritime and Structural Engineering, Department of Mechanical Engineering, Swiss Federal Laboratories for Materials Testing and Research
Authors: Weber, F. (Ekstern), Høgsberg, J. B. (Intern), Krenk, S. (Intern)
Pages: 123-134
Publication date: 2010
Main Research Area: Technical/natural sciences

**Publication information**

Journal: Journal of Structural Engineering
Volume: 136
Issue number: 2
ISSN (Print): 0733-9445
Ratings:
BFI (2017): BFI-level 2
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 1.91 SJR 1 SNIP 1.53
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.409 SNIP 1.664 CiteScore 1.62
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.9 SNIP 2.392 CiteScore 1.93
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 1.924 SNIP 2.607 CiteScore 2.01
ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 1.81 SNIP 2.116 CiteScore 1.57
ISI indexed (2012): ISI indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 1.584 SNIP 2.001 CiteScore 1.38
Resonant vibration control of wind turbine blades

The paper deals with introduction of damping to specific vibration modes of wind turbine blades, using a resonant controller with acceleration feedback. The wind turbine blade is represented by three-dimensional, two-node finite elements in a local, rotating frame of reference. The element formulation accounts for arbitrary mass density distributions, general elastic crosssection properties and geometric stiffness effects due to internal stresses. A compact, linear formulation for aerodynamic forces with associated stiffness and damping terms is established and added to the structural model. The efficiency of the resonant controller is demonstrated for a representative turbine blade exposed to turbulent wind loading. It is found that the present explicit tuning procedure yields close to optimal tuning, with very limited modal spill-over and effective reduction of the vibration amplitudes.

General information
State: Published
Organisations: Department of Mechanical Engineering, Coastal, Maritime and Structural Engineering
Authors: Svendsen, M. N. (Intern), Krenk, S. (Intern), Høgsberg, J. B. (Intern)
Pages: 543-553
Publication date: 2010

Host publication information
Title of host publication: TORQUE 2010 : The Science of Making Torque from Wind
Main Research Area: Technical/natural sciences
Conference: TORQUE 2010, Crete, Greece, 01/01/2010
Resonant control, Rotating beam elements, Aeroelastic beam elements, Edgewise damping
Source: orbit
Source-ID: 271522
Publication: Research - peer-review › Article in proceedings – Annual report year: 2010

Design of resonant vibration absorbers with filtered feedback

General information
State: Published
Organisations: Coastal, Maritime and Structural Engineering, Department of Mechanical Engineering
Authors: Krenk, S. (Intern), Høgsberg, J. B. (Intern)
Publication date: 2009
Main Research Area: Technical/natural sciences
Optimal resonant control of flexible structures

When introducing a resonant controller for a particular vibration mode in a structure this mode splits into two. A design principle is developed for resonant control based on equal damping of these two modes. First the design principle is developed for control of a system with a single degree of freedom, and then it is extended to multi-mode structures. A root locus analysis of the controlled single-mode structure identifies the equal modal damping property as a condition on the linear and cubic terms of the characteristic equation. Particular solutions for filtered displacement feedback and filtered acceleration feedback are developed by combining the root locus analysis with optimal properties of the displacement amplification frequency curve. The results are then extended to multi-mode structures by including a quasi-static representation of the background modes in the equations for the damped mode. Applications to multi-degree-of-freedom systems are illustrated by idealized models of a piezoelectric sensor-actuator device on a beam and an accelerometer-actuator device on a cable. In both cases near-ideal response characteristics are obtained, when including the quasi-static correction of the modal properties.
Resonant damping of flexible structures

General information
State: Published
Organisations: Department of Mechanical Engineering, Coastal, Maritime and Structural Engineering
Authors: Krenk, S. (Intern), Høgsberg, J. B. (Intern)
Publication date: 2009

Host publication information
Title of host publication: ECCOMAS Thematic conference on Computational Methods in Structural Dynamics and Earthquake Engineering : COMPDYN 2009
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 247664
Publication: Research - peer-review › Article in proceedings – Annual report year: 2009

Energy dissipation control of magneto-rheological damper

The efficiency of a damper depends on the amount of energy dissipation during a typical cycle experienced by the damper. For viscous dampers this leads to substantial frequency dependence. For dampers with hysteresis the tuning and efficiency also depends on the apparent amplitude of the damper response. For irregular damper response the amplitude is evaluated as the magnitude of closed hysteresis loops. These loops are identified in real time by the rainflow rules, stored in a Markov-type matrix and used to predict the magnitude of subsequent closed loops. From this prediction the properties of the semi-active damper are adjusted in real time to optimize performance and avoid clamping of the damper. The efficiency of this adaptive tuning procedure is illustrated for a magneto-rheological damper model.

General information
State: Published
Organisations: Coastal, Maritime and Structural Engineering, Department of Mechanical Engineering
Tuned mass absorbers on damped structures under random load
A substantial literature exists on the optimal choice of parameters of a tuned mass absorber on a structure excited by a force or by ground acceleration with random characteristics in the form of white noise. In the absence of structural damping the optimal frequency tuning is determined from the mass ratio alone, and the damping can be determined subsequently. Only approximate results are available for the influence of damping in the original structure, typically in the form of series expansions. In the present paper it is demonstrated that for typical mass ratios in the order of a few percent the classic stochastic frequency tuning gives the same standard deviation of the response amplitude within a margin of 0.001 as when using the classic frequency tuning for harmonic load variation, and then optimizing the damping separately. Simple approximate, but very accurate, expressions are obtained for the response variance of a structure with initial damping in terms of the mass ratio and both damping ratios. Within this format the optimal tuning of the absorber turns out to be independent of the structural damping, and a simple explicit expression is obtained for the equivalent total damping.

General information
State: Published
Organisations: Coastal, Maritime and Structural Engineering, Department of Mechanical Engineering
Authors: Krenk, S. (Intern), Høgsberg, J. B. (Intern)
Pages: 408-415
Publication date: 2008
Main Research Area: Technical/natural sciences

Publication information
Journal: Probabilistic Engineering Mechanics
Volume: 23
Issue number: 4
ISSN (Print): 0266-8920
Ratings:
BFI (2017): BFI-level 2
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 2
Scopus rating (2016): SJR 0.834 SNIP 1.632 CiteScore 1.9
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.313 SNIP 1.967 CiteScore 2.1
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.65 SNIP 1.958 CiteScore 2.08
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 1.543 SNIP 2.054 CiteScore 2.6
ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 1.318 SNIP 1.998 CiteScore 1.62
ISI indexed (2012): ISI indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 1.817 SNIP 2.446 CiteScore 2.04
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 1.141 SNIP 1.953
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 1.451 SNIP 2.024
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 1.5 SNIP 2.317
Web of Science (2008): Indexed yes
Tuned mass dampers on damped structures

General information
State: Published
Organisations: Coastal, Maritime and Structural Engineering, Department of Mechanical Engineering
Authors: Krenk, S. (Intern), Høgsberg, J. B. (Intern)
Publication date: 2008

Host publication information
Title of host publication: 7th European Conference on Structural Dynamics
Place of publication: Southampton, United Kingdom
Publisher: University of Southampton
Editor: Brennan, M.
Main Research Area: Technical/natural sciences
Conference: 7th European Conference on Structural Dynamics, Southampton, United Kingdom, 07/07/2008 - 07/07/2008
Electronic versions:
E61.pdf
Source: orbit
Source-ID: 223472
Publication: Research - peer-review › Article in proceedings – Annual report year: 2008

Adaptive tuning of elasto-plastic damper
Hysteretic dampers are frequency independent, and thereby potentially effective for several structural vibration modes, provided that the inherent amplitude dependence can be controlled. An adaptive tuning procedure is proposed, aiming at elimination of the amplitude dependence by adjusting the damper parameter(s) with respect to the magnitude of the damper motion. The procedure is demonstrated in terms of the bilinear elasto-plastic damper model, and optimality corresponds to maximum modal damping. A parametric solution for the damping ratio is obtained by a two-component system reduction technique, and maximization leads to an amplitude dependent expression for the optimal yield level. The amplitude is predicted from the most recent extremum of the damper response, and simultaneously used to adjust the yield level. Numerical examples demonstrate that the adaptive tuning procedure succeeds in controlling the amplitude dependence, resulting in equal damping for the first vibration modes.

General information
State: Published
Organisations: Coastal, Maritime and Structural Engineering, Department of Mechanical Engineering
Authors: Høgsberg, J. R. (Intern), Krenk, S. (Intern)
Pages: 928-940
Publication date: 2007
Modelling of Dampers and Damping in Structures

The present thesis consists of an extended summary and four papers concerning damping of structures and algorithmic damping in numerical analysis. The first part of the thesis deals with the efficiency and the tuning of external collocated dampers acting on flexible structures. The dynamics, and thereby the damping, of flexible structures are generally described in terms of the dominant vibration modes. A system reduction technique, where the damped vibration mode is constructed as a linear combination of the undamped mode shape and the mode shape obtained by locking the damper, is applied. This two-component representation leads to a simple solution for the modal damping representing the natural frequency and the associated damping ratio. It appears from numerical examples that this system reduction technique provides very accurate results. Analytical expressions for the optimal tuning and the maximum attainable damping are found by maximizing the expression for the damping ratio. The theory is formulated for linear damper models, but may also be applied for non-linear dampers in terms of equivalent linear parameters for stiffness and damping, respectively. The format of the expressions obtained by the present system reduction technique is similar to that for damping of cables. The characteristics of dampers are governed by the relation between the damping component (energy dissipation) and the stiffness component (restoring force). This relation is conveniently described by the representative angle of the damper force in phase-plane. It is demonstrated how efficiency of the damper increases with the phase angle, and in particular how phase lead, where the damper force acts ahead of velocity, implies large damping. However, phase lead is equivalent to negative stiffness, and therefore only realizable by means of active control. The present thesis demonstrates how stiffness affects both the performance and the tuning of the damper. The final part of the thesis considers algorithmic damping in connection with Newmark time integration. The damping characteristics of the Newmark method are improved by introducing a negative damping component, governed by a first order linear filter. This additional force component is designed so that it compensates for the undesirable damping introduced by the Newmark method in the low-frequency range, while it provides adjustable high-frequency damping. The filter method gives a general synthesis for the various alpha-modifications of the Newmark method and an improved weighting of the external load.
Linear control strategies for damping of flexible structures

Starting from the two-component representation technique for damping of structures the possible increase in damping efficiency obtained by introducing collocated active damping is illustrated. The two-component representation of the damped vibration mode is constructed as a linear combination of the undamped mode shape and the mode shape obtained by locking the damper. This leads to a simple set of equations of motion, which in the frequency domain gives an accurate solution for the complex-valued natural frequency, and thereby for the modal damping. This solution shows that attainable damping increases with the phase angle of the damper, and that improved damping efficiency thus follows from the ability of an active device to produce a force acting ahead of velocity. Phase lead is equivalent to negative stiffness, and the effect of negative stiffness is illustrated by a radiation condition on a cable. Simple linear filters, with desirable low-pass properties, are presented as simple means for implementing phase lead.
Damping of cables by a transverse force

**General information**
State: Published
Organisations: Coastal, Maritime and Structural Engineering, Department of Mechanical Engineering
Authors: Krenk, S. (Intern), Høgsberg, J. R. (Intern)
Pages: 340-348
Publication date: 2005
Main Research Area: Technical/natural sciences

**Publication information**
Journal: Journal of Engineering Mechanics
Volume: 131
Issue number: 4
ISSN (Print): 0733-9399
Ratings:
- BFI (2017): BFI-level 2
- Web of Science (2017): Indexed Yes
- BFI (2016): BFI-level 2
- Scopus rating (2016): CiteScore 1.62 SJR 0.628 SNIP 1.147
- BFI (2015): BFI-level 2
- Scopus rating (2015): SJR 0.71 SNIP 1.078 CiteScore 1.42
- BFI (2014): BFI-level 2
- Scopus rating (2014): SJR 0.85 SNIP 1.363 CiteScore 1.42
- BFI (2013): BFI-level 2
- Scopus rating (2013): SJR 0.875 SNIP 1.584 CiteScore 1.45
- ISI indexed (2013): ISI indexed yes
- Web of Science (2013): Indexed yes
- BFI (2012): BFI-level 2
- Scopus rating (2012): SJR 1.005 SNIP 1.824 CiteScore 1.35
- ISI indexed (2012): ISI indexed yes
- Web of Science (2012): Indexed yes
- BFI (2011): BFI-level 2
- Scopus rating (2011): SJR 0.829 SNIP 1.449 CiteScore 1.16
- ISI indexed (2011): ISI indexed yes
- BFI (2010): BFI-level 2
- Scopus rating (2010): SJR 1.023 SNIP 1.555
- BFI (2009): BFI-level 2
- Scopus rating (2009): SJR 1.033 SNIP 1.53
- BFI (2008): BFI-level 2
- Scopus rating (2008): SJR 1.046 SNIP 1.457
- Scopus rating (2007): SJR 1.515 SNIP 1.933
- Web of Science (2007): Indexed yes
Properties of time integration with first order filter damping

General information
State: Published
Organisations: Coastal, Maritime and Structural Engineering, Department of Mechanical Engineering
Authors: Krenk, S. (Intern), Høgsberg, J. R. (Intern)
Pages: 547-566
Publication date: 2005
Main Research Area: Technical/natural sciences

Publication information
Volume: 64
ISSN (Print): 0029-5981
Ratings:
BFI (2017): BFI-level 2
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 2.64 SJR 1.743 SNIP 1.566
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.912 SNIP 1.689 CiteScore 2.67
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.935 SNIP 1.927 CiteScore 2.73
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 2.415 SNIP 1.894 CiteScore 2.8
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 2.47 SNIP 2.103 CiteScore 2.7
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 2.193 SNIP 1.935 CiteScore 2.47
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 2.177 SNIP 1.717
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Linear control strategies for structural damping

General information
State: Published
Organisations: Coastal, Maritime and Structural Engineering, Department of Mechanical Engineering
Authors: Høgsberg, J. R. (Intern), Krenk, S. (Intern)
Publication date: 2004

Host publication information
Title of host publication: Proceedings of the 7th International Conference on Motion and Vibration Control
Volume: Paper No. 60, CD-ROM
Place of publication: St. Louis, Missouri
Publisher: Washington University
Main Research Area: Technical/natural sciences
Conference: 7th International Conference on Motion and Vibration Control, St. Louis, Missouri, 01/01/2004
Source: orbit
Source-ID: 155793
Publication: Research - peer-review › Article in proceedings – Annual report year: 2004

Newmark integration with filter properties

General information
State: Published
Organisations: Coastal, Maritime and Structural Engineering, Department of Mechanical Engineering
Authors: Høgsberg, J. R. (Intern), Krenk, S. (Intern)
Number of pages: 209
Pages: 145-147
Publication date: 2004

Host publication information
Title of host publication: NSCM-17: Proceedings of the 17th Nordic Seminar on Computational Mechanics
Place of publication: Stockholm
Publisher: KTH Mechanics
Editors: Eriksson, A., Månsson, J., Tibert, G.
Optimal damping of cables by an external damper

General information
State: Published
Organisations: Maritime Engineering, Department of Mechanical Engineering
Authors: Krenk, S. (Intern), Høgsberg, J. R. (Intern)
Pages: 419-426
Publication date: 2003

Host publication information
Title of host publication: Proceedings of the Fifth International Symposium on Cable Dynamics
Place of publication: AIM, Université de Liège, Belgium
Main Research Area: Technical/natural sciences
Conference: Fifth International Symposium on Cable Dynamics, Santa Margherita Ligure, Italy, 01/01/2003
Source: orbit
Source-ID: 25663
Publication: Research - peer-review › Article in proceedings – Annual report year: 2003

Bulingsinitieret delaminering af rørformet bilag udsat for ydre overtryk

General information
State: Published
Organisations: Coastal, Maritime and Structural Engineering, Department of Mechanical Engineering
Authors: Høgsberg, J. R. (Intern)
Pages: 10-14
Publication date: 2001
Main Research Area: Technical/natural sciences

Publication information
Journal: Journal of The Danish Ceramic Society
Volume: 4
Issue number: 1
Original language: Danish
Source: orbit
Source-ID: 190107
Publication: Research - peer-review › Journal article – Annual report year: 2001

Projects:

Resonant Piezoelectric Shunt Damping of Structures
Department of Mechanical Engineering
Period: 01/10/2016 → 30/09/2019
Number of participants: 4
Phd Student:
Toftekær, Johan Frederik (Intern)
Supervisor:
Benjeddou, Ayech (Ekstern)
Krenk, Steen (Intern)
Main Supervisor:
Høgsberg, Jan Becker (Intern)

Financing sources
Source: Internal funding (public)
Name of research programme: Samfinansieret - Andet
Project: PhD
Damping of Torsional Beam Vibrations
Department of Mechanical Engineering
Period: 01/09/2016 → 31/08/2019
Number of participants: 3
Phd Student:
Hoffmeyer, David (Intern)
Supervisor:
Krenk, Steen (Intern)
Main Supervisor:
Høgsberg, Jan Becker (Intern)

Financing sources
Source: Internal funding (public)
Name of research programme: Institut stipendie (DTU)
Project: PhD

Damping of overhead transmission line systems
Department of Mechanical Engineering
Period: 15/01/2015 → 10/05/2018
Number of participants: 3
Phd Student:
Kliem, Mathias (Intern)
Supervisor:
Berggreen, Christian (Intern)
Main Supervisor:
Høgsberg, Jan Becker (Intern)

Financing sources
Source: Internal funding (public)
Name of research programme: Samfinansieret - Andet
Project: PhD

Enhanced evaluation of structural damping using Operational Modal Analysis
Department of Mechanical Engineering
Period: 15/01/2014 → 17/09/2017
Number of participants: 5
Phd Student:
Bajric, Anela (Intern)
Main Supervisor:
Høgsberg, Jan Becker (Intern)
Examiner:
Thomsen, Jon Juel (Intern)
Chatzi, Eleni (Ekstern)
Peeters, Bart (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Institut stipendie (DTU)
Project: PhD

Optimization of materials for nonlinear dynamic perfromance
Department of Mechanical Engineering
Period: 15/03/2013 → 01/09/2016
Number of participants: 6
Phd Student:
Frandsen, Niels Morten Marslev (Intern)
Modeling and Analysis of Coupled wind Turbine Blades

Department of Mechanical Engineering
Period: 01/11/2012 → 07/04/2016
Number of participants: 7
Phd Student:
Couturier, Philippe (Intern)
Supervisor:
Høgsberg, Jan Becker (Intern)
Winther Stærdahl, Jesper (Ekstern)
Main Supervisor:
Krenk, Steen (Intern)
Examiner:
Legarth, Brian Nyvang (Intern)
Lund, Erik (Ekstern)
Saravanos, Dimitris (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Ansat eksternt
Project: PhD

Modeling of displacements of flexible pavements under moving load

Department of Mechanical Engineering
Period: 01/07/2012 → 30/09/2016
Number of participants: 5
Phd Student:
Madsen, Stine Skov (Intern)
Main Supervisor:
Pedersen, Niels Leergaard (Intern)
Examiner:
Høgsberg, Jan Becker (Intern)
Kallivokas, Loukas F. (Ekstern)
Vabbersgaard Andersen, Lars (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Offentlig finansiering

Relations
Publications:
Dynamic Modeling of Pavements with Application to Deflection Measurements
Damping of Wind Turbine Tower Vibrations
Department of Mechanical Engineering
Period: 15/03/2012 → 19/01/2017
Number of participants: 7
Phd Student:
Brodersen, Mark Laier (Intern)
Supervisor:
Jensen, Jørgen Juncher (Intern)
Pedersen, Mikkel Melters (Ekstern)
Main Supervisor:
Høgsberg, Jan Becker (Intern)
Examiner:
Pedersen, Niels Leergaard (Intern)
Basu, Biswajit (Ekstern)
Neild, Simon Andrew (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Forskningsrådsfinansiering

Relations
Publications:
Damping of wind turbine tower vibrations
Project: PhD

Hybrid Testing of Wind Turbine Blades
Department of Mechanical Engineering
Period: 01/12/2011 → 04/07/2016
Number of participants: 8
Phd Student:
Høgh, Jacob Herold (Intern)
Supervisor:
Branner, Kim (Intern)
Schmidt, Jacob Wittrup (Intern)
Stang, Henrik (Intern)
Main Supervisor:
Berggreen, Christian (Intern)
Examiner:
Høgsberg, Jan Becker (Intern)
Barton, Janice (Ekstern)
Lund, Erik (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: 1/3 FUU, 1/3 inst 1/3 Andet

Relations
Publications:
Hybrid Simulation of Composite Structures
Project: PhD

Optimal design of porous materials
Department of Mechanical Engineering
Period: 01/09/2011 → 19/03/2015
Number of participants: 7
Phd Student:
Modeling of Rotating Structures

Department of Mechanical Engineering
Period: 01/09/2010 → 28/04/2014
Number of participants: 5
Phd Student:
Nielsen, Martin Bjerre (Intern)
Main Supervisor:
Krenk, Steen (Intern)
Examiner:
Høgsberg, Jan Becker (Intern)
Cardona, Alberto (Ekstern)
Romero, Ignacio (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Forskningsrådsfinansiering
Project: PhD

Hybrid method simulation of slender marine structures

Department of Mechanical Engineering
Period: 01/03/2010 → 23/02/2015
Number of participants: 6
Phd Student:
Christiansen, Niels Hørbye (Intern)
Supervisor:
Sødahl, Nils (Ekstern)
Main Supervisor:
Høgsberg, Jan Becker (Intern)
Examiner:
Jensen, Jørgen Juncher (Intern)
Larsen, Carl Martin (Ekstern)
Volnei Sudati Sagrilo, Luis (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Institut stipendie (DTU) Samf.
Project: PhD

Rullekæders Dynamik: Teoretisk Modellering og Analyse
Period: 01/01/2010 → 19/03/2015
Number of participants: 5
Phd Student:
Fuglede, Niels (Intern)
Main Supervisor:
Thomsen, Jon Juel (Intern)
Examiner:
Høgsberg, Jan Becker (Intern)
Eberhard, Peter (Ekstern)
Fidlin, Alexander (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Institut stipendie (DTU)
Project: PhD

Modelling and Control of Semi-Active Dampers
Department of Mechanical Engineering
Period: 01/06/2008 → 28/03/2012
Number of participants: 7
Phd Student:
Bhowmik, Subrata (Intern)
Supervisor:
Krenk, Steen (Intern)
Weber, Felix (Ekstern)
Main Supervisor:
Høgsberg, Jan Becker (Intern)
Examiner:
Jensen, Jørgen Juncher (Intern)
Basu, Biswajit (Ekstern)
Nielsen, Søren R. K. (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Offentlig finansiering
Project: PhD

Modalkontrol af vindmøller
Department of Mechanical Engineering
Period: 01/01/2008 → 06/04/2011
Number of participants: 7
Phd Student:
Svendsen, Martin Nymann (Intern)
Supervisor:
Høgsberg, Jan Becker (Intern)
Svendsen, Rasmus (Ekstern)
Main Supervisor:
Krenk, Steen (Intern)
Examiner:
Nielsen, Søren R. K. (Ekstern)
Preumont, André (Ekstern)
Rixen, Daniel J. (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: ErhvervsPhD-ordningen VTU
Project: PhD
Modelling of Dampers and Damping in structures

Department of Mechanical Engineering
Period: 01/09/2002 → 22/05/2006
Number of participants: 5
Phd Student:
Høgsberg, Jan Becker (Intern)
Main Supervisor:
Krenk, Steen (Intern)
Examiner:
Nielsen, Søren R. K. (Ekstern)
Brennan, Michael John (Ekstern)
Preumont, André (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Forskningsrådsfinansiering
Project: PhD